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Perceptual memory refers to experience-induced changes in perceptual processing of particular objects or scenes. Part 1 of this report summarizes the results of 8 studies of the role of perceptual memory in recognition memory. The hypothesis was confirmed that perceptual memory contributes to the feeling of familiarity that observers sometimes experience even when they lack explicit memory for previously encountered objects. Part 2 summarizes the results of 14 studies of a by-product of perceptual memory called novel popout. The theory was confirmed that novel popout arises from the automatic disinhibition of processing of objects that fail to match top-down effects of perceptual memory.

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STUDIES OF PERCEPTUAL MEMORY: FINAL REPORT

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University of Utah

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Perceptual memory refers to long-term changes in perceptual processing wrought by particular perceptual experiences. Perceptual memory is a form of implicit memory in that it is not dependent on the observer's explicit recollection of either the perceptual experiences themselves or the perceptual-memory consequences of these experiences. Perceptual memory illustrates a subtle, yet powerful, way that prior experience, however simple and innocuous it may seem to be, can affect, quite literally, one's view of the world. This report summarizes the major findings of a three-year research program on perceptual memory. Rather than investigating perceptual memory per se, the research focused on the effects that perceptual memory might have on other processes. In particular, we investigated the role of perceptual memory in recognition memory and a possible emergent phenomenon of perceptual memory called novel popout.

Part 1: Role of Perceptual Memory in Recognition Memory

Recognition memory tasks typically are composed of a study phase followed by a test phase. Words, or other items, are presented during the study phase, often with no explicit forewarning of the impending test phase. In the test phase, these old items are intermixed sequentially with new items, and observers classify each item as old or new. According to one class of theory, old/new judgments are influenced, in varying degrees, by two factors: explicit memory for old items and a "feeling of familiarity". Johnston, Dark, & Jacoby (1985) explored the possibility that perceptual memory may underlie the feeling of familiarity.

Perceptual memory for old items is often indexed in terms of the "fluency" with which they are perceived, old items being perceived more fluently than new items (e.g., Jacoby & Dallas, 1981). Johnston et al. (1985) adapted a standard recognition-memory task to allow the measurement of perceptual fluency of old and new test items in terms of the speed with which they could be identified when they emerged gradually from a field of visual noise. Following an identification attempt, the item was fully clarified and the observer judged it as old or new. The items were words in one study and nonwords in a second study. The main hypothesis, called the fluency-cue hypothesis, was that observers sometimes base their recognition judgments on the speed, or fluency, with which they identify items. On the assumption that observers rely on the fluency cue to the extent that they lack explicit memory for old words, a subsidiary hypothesis was that observers depend more on fluency cues when nonwords are used as the memory items than when words are used. There were four main findings: (1) old items were perceived more fluently than new items; (2) regardless of their actual old/new status, items judged old were perceived more fluently than items judged new; (3) judgment accuracy was higher for words than for nonwords; and (4) the fluency difference between old and new judgments was greater for nonwords than for words. The first effect defines perceptual memory for old items, the second conforms to the fluency-cue hypothesis, the third indicates that explicit memory is higher for words than for nonwords, and the fourth conforms to the subsidiary hypothesis that the reliance on the fluency cue is relatively high when explicit memory for old items is relatively low. These findings provided the main motivation for the series of eight studies summarized below and reported in greater detail by Johnston, Hawley, and Elliott (1991).

Experiments 1-3

We reasoned that if observers use the speed with which they identify test items as a cue for making recognition judgments, then we should be able to control their judgments by experimentally controlling the speed with which the items are identified.

Method

The main manipulation in Experiments 1-3 was the speed with which the test items emerged from noise. Slow-clearing items became completely clear in 7.5 s, and fast-clearing items in 4.5 s. Slow- and fast-clearing items were presented in random order in the test phase of a recognition-memory task. An identification attempt caused any remaining noise to be instantly removed, at which point an old/new judgment was made. Formally, the design was a 2 X 2 X 2 (Clearing Rate X Actual Old/New Status X Judged Status) factorial with repeated measures on all factors. The first two factors were established by the experimenters and the last factor by the observers' judgments. The dependent variables were latency of identification and, for the first two factors, percentage of items judged old. The main prediction, derived from the fluency-cue hypothesis, was that the percentage of old judgments would be higher for fast-clearing items than for slow-clearing items.

An independent sample of 32 observers was recruited from introductory psychology classes to serve in each study. The three experiments differed only in terms of the nature of the study task (naming vs. vowel counting) and the items (words vs. nonwords). Naming of words was used in Experiment 1, naming of nonwords was used in Experiment 2, and counting vowels of

words was used in Experiment 3. These differences were produced a wide range both explicit memory and perceptual memory. Both forms of memory were relatively high in Experiment 1, both forms were relatively low in Experiment 2, and explicit memory was relatively low and perceptual memory relatively high in Experiment 3. We expected to observe the greatest reliance on perceptual fluency as a cue for making recognition judgments in Experiment 3. Not only did observers have relatively little explicit memory on which to rely in that experiment, but they had a relatively high level of perceptual memory, making perceptual fluency a valid basis for old/new judgments.

Results and Discussion

The identification latencies for the three experiments are summarized in Table 1, and the percentages of old judgments are summarized in Table 2. Pooled across experiments, the latency data show that fast-clearing words were identified faster than slow-clearing words, that old words were identified faster than new words, and that words judged old were identified faster than words judged new regardless of their actual old/new status. Thus, the clearing-rate manipulation had the intended effect on identification latency, perceptual memory for old words was observed, and there was an apparent reliance on the fluency cue. However, the most important result shows up clearly in the percentages of old judgments. In particular, the manipulation of identification speed, via clearing rate, had no effect on the likelihood of old judgments. That is, we were not able to manipulate observers' judgments by making them see some items faster than other items. Thus, the fluency-cue hypothesis received no support from the data of Experiments 1-3.

Table 1

Mean Latency of Identification of Test Items in Experiments 1-3

Experiment/ Clearing Rate	Actual/Judged Status: Old		New	
	Old	New	Old	New
Experiment 1				
Slow	1,481	1,737	1,789	1,876
Fast	1,313	1,521	1,455	1,670
Experiment 2				
Slow	3,066	3,401	3,223	3,526
Fast	2,403	2,640	2,388	2,647
Experiment 3				
Slow	1,721	1,913	1,847	2,049
Fast	1,495	1,644	1,533	1,811

Note. Mean latencies in this and other tabular summaries are rounded to the nearest millisecond.

Table 2

Mean Percentage of Test Items Judged Old in Experiments 1-3

Experiment/ Clearing Rate	Actual Status: Old	New
Experiment 1		
Slow	72%	35%
Fast	73%	39%
Experiment 2		
Slow	40%	38%
Fast	42%	39%
Experiment 3		
Slow	40%	26%
Fast	39%	27%

Note. Mean percentages in this and other tabular summaries are rounded to the nearest whole number.

Experiment 4

It might be argued that the manipulation of clearing rate did not faithfully simulate the perceptual fluency differences between old and new items. Indeed, the effects of perceptual memory (i.e., actual old/new status of items) and clearing rate on item identifications were discernably different. In contrast to fast clearing, perceptual memory allowed items to be seen relatively quickly even while they were still relatively noisy. Thus, the natural fluency cue provided by perceptual memory may have two attributes: the speed with which items can be identified, which is simulated by clearing rate, and the signal-to-noise ratio at which they can be identified, which is not simulated by clearing rate. Experiment 4 attempted to simulate both attributes by semantically priming some of the test words. For example, if primed by the word DOCTOR, the test word NURSE should be seen both relatively quickly and at a relatively low signal-to-noise ratio.

Method

A continuous recognition task was used in which study and test words were intermixed in a long series. As before, a test word was obscured by visual noise when it first appeared. The noise was then removed at the rate of one pixel every 20 ms, such that tests words would become completely clear in 6 s. An identification attempt caused any remaining noise to be removed instantly at which time the observer made an old/new judgment. Some of the test words were preceded by a semantically related study word. Thus, the design was a 2 X 2 X 2 (Semantic Priming X Actual Old/New Status X Judged Status) factorial with repeated measures on all

factors. Latency of identification was examined as a function of all three factors and percentage of old judgments as a function of the first two factors. The primary prediction, derived from the fluency-cue hypothesis, was that semantic priming would increase the likelihood of old judgments, even for new items.

Results and Discussion

The identification latencies and percentages of old judgments are summarized in the top and bottom halves, respectively, of Table 3.

Table 3

Mean Latency of Identification and Percentage Old Judgments for Test Words in Experiment 4

Measure/Semantic Priming	Actual/Judged Status: Old/Old	Old/New	New/Old	New/New
Identification Latency				
Nonprimed	1,491	1,546	1,157	1,782
Primed	1,310	1,378	853	1,593
Percentage Old Judgments				
Nonprimed	48%		13%	
Primed	48%		8%	

Overall, latency of identification was less for primed words than for nonprimed words, indicating that semantic priming had the intended effect, less for old words than for new words, indicating perceptual memory, and less for words judged old than for those judged new, indicating the use of a fluency cue. However, the use of a fluency cue was counterindicated by the lack of a priming effect on the likelihood of old judgments. Thus,

despite the fact that semantic priming duplicated both of the assumed attributes of perceptual fluency, it failed to dupe observers into making old judgments.

The null effect of semantic priming on recognition judgments might have been convincing evidence against the fluency-cue hypothesis were it not arguable, on the basis of the findings of Jacoby and Whitehouse (1989), that observers attributed their fluent perceptions of primed words correctly to semantic priming rather than incorrectly to perceptual memory. That is, observers may attribute their fluent perception of the test word NURSE to the fact that they have just seen the prime word DOCTOR. It may only be when there is not an obvious situational explanation for fluent perception that observers experience the feeling of familiarity and are inclined to make an old judgment. Therefore, being somewhat stymied in our attempt to simulate the full perceptual and attributional properties of perceptual memory, we opted to take a new tact altogether. In particular, rather than attempting to test directly the fluency-cue hypothesis, we decided to test the alternative hypothesis that the usual association of fluent perceptions with old judgments is due to item selection.

Experiment 5

The fluency-cue hypothesis is based on the consistent finding that identification latencies are shorter for items judged old than for those judged new. The hypothesis assumes a causal relationship between the perceptual fluency dynamics underlying identification latencies, the feeling of familiarity, and the tendency to make an old judgment.

However, the alternative hypothesis is that the relationship between perceptual fluency and old judgments is not a causal one but due rather to item selection (e.g., Watkins & Gibson, 1988). According to the item-selection hypothesis, the same items that "feel familiar" also tend to be those that are easily perceptible. Experiment 5 tested this item-selection hypothesis by separating the item identifications and old/new judgments into separate test stages. According to the fluency-cue hypothesis, this temporal segregation should nullify the cue utility of perceptual fluency and, thus, remove the correlation between identification latency and percentage of old judgments. According to the item-selection hypothesis, the same items that are most quickly identified in the identification stage should be those that are most likely judged old in the judgment stage, so the correlation should remain intact.

Method

In order to minimize any effects of either explicit memory or perceptual memory on the possible item-based association between perceptual fluency and recognition judgments, no words were actually presented during the "study" phase. However, observers were told that words were presented subliminally. Three groups of observers were differentiated in terms of the nature of the testing that followed the bogus study stage. In the _together_ group, the identification and judgment tests were conducted successively on each item in turn, just as was done in the preceding studies. In the _identification-first_ group, all items were identified on one block of test trials and then judged old or new on a separate block of trials. In the _judgment-first_ group, the judgment

block preceded the identification block. Because all test words were new, the only independent variable manipulated aside from group was the observer-defined variable of judged old/new status of test words. Thus, the design was a 3 X 2 (Group X Judged Status) factorial with repeated measures on the second factor. According to the fluency-cue hypothesis, the usual correlation between identification latency and old judgments should be restricted to the together group. According tne item-selection hypothesis, the correlation should show up in all three groups.

Results and Discussion

The identification latency data, summarized in Table 4, are in accord with the fluency-cue hypothesis and run contrary to the item-selection hypothesis. That is, the usual difference in identification latency between items judged old and items judged new was restricted to the together group. If this difference were due to item characteristics, then it should have appeared in all three groups.

Table 4

Mean Latency of Identification of Test Items in Experiment 5

	Judged Status	
Group	Old	New
Identification-First	1,649	1,641
Judgment-First	1,326	1,322
Together	1,518	2,467

To gain further insight into the apparent use of a fluency cue in the together group, the items were partitioned into fluency quartiles based on mean latency of identification in the identification-first group, the one

group in which these latencies could not have been affected by either prior presentations of the items (judgment-first group) or concurrent recognition judgments (together group). These quartiles were deemed to reflect the natural perceptual fluency of the words. According to the item-selection argument, percentage of old judgments should increase across fluency quartiles in all three groups. However, according to the fluency-cue hypothesis, this increase should be limited to the together group. As Table 5 demonstrates, the data conform to the fluency-cue hypothesis and run counter to the item-selection hypothesis.

Table 5

Percentage of Old Judgments for Each Group in Experiment 5
as a Function of Fluency Quartile

Group	Fluency Quartile			
	1 (low)	2	3	4 (high)
Identification First	50%	54%	53%	57%
Judgment First	53%	52%	53%	47%
Together	40%	54%	61%	67%

Experiments 6 and 7

The fluency quartiles established in Experiment 5 were used in the remaining studies as the manipulation of perceptual fluency. The absence of old items in Experiment 5 ensures that any contribution of explicit memory to recognition judgments would be absolutely nil, thereby maximizing the potential dependency on fluency cues. Experiments 6 and 7 tested the hypothesis that this dependency on fluency cues, as indicated by the effect of fluency quartile on percentage of old judgments, is an inverse function of the amount of explicit memory for old items. To

produce different degrees of explicit memory for old words, level of processing of study words was manipulated across Experiments 6 and 7. Observers counted vowels in Experiment 6 and named the words in Experiment 7. We predicted that judgment accuracy would increase across experiments, owing to the increase in explicit memory, and that the effect of fluency quartile would decrease, owing to the decreased dependence on perceptual fluency in making recognition judgments. Both a together group and an identification-first group were run in both experiments. We predicted that any effect of fluency quartile on recognition judgments would be confined to the together group, this being the only group in which fluency cues produced by slowly clearing test words would be available to observers for use in making old/new judgments.

Results and Discussion

The main findings are summarized in Table 6. The predictions were confirmed. Judgment accuracy was higher in Experiment 7 than in Experiment 6, confirming the predicted increase in explicit memory with level of processing of study items. Percentage of old judgments increased with fluency quartile only in the together group of Experiment 6, confirming the predicted use of fluency cues only when they are both available and needed. It is noteworthy also that judgment accuracy was greater in the together group of Experiment 6 than in the identification-first group. This finding indicates that the use of the fluency cue under conditions of low explicit memory facilitates recognition judgments. Thus, the feeling of familiarity can be a reliable basis upon which to make old/new judgments. One methodological

implication of this is that the use of recognition memory as a index of explicit memory may not always be justified.

Table 6

Percentage of Old Judgments for Old and New Words Both Groups of Experiments 6 and 7 as a Function of Fluency Quartile

Experiment/Group	Actual Status	Fluency Quartile 1 (low)	2	3	4 (high)
Experiment 6					
Together	Old	49%	53%	53%	60%
	New	39%	43%	46%	50%
Identify-First	Old	47%	46%	51%	47%
	New	41%	47%	47%	46%
Experiment 7					
Together	Old	63%	70%	69%	65%
	New	30%	35%	33%	34%
Identify-First	Old	61%	64%	58%	56%
	New	42%	47%	44%	43%

Experiment 8

Our final study in this line of research sought to demonstrate that the apparent dependency of recognition judgments on fluency cues in Experiment 6 was not in some way an artifact of observers having to explicitly identify items before judging them old or new. Thus, Experiment 6 was replicated precisely except that the requirement to explicitly identify test words as they came into view was removed. As soon as the words were sufficiently clear, observers merely made a recognition judgment on them.

Results and Discussion

As in Experiment 6, the percentage of old judgments increased directly across fluency quartiles. A direct statistical comparison between

Experiments 6 and 8 indicated no reliable difference in the data. Thus, the use of perceptual fluency as a cue for making recognition judgments does not appear to be an artifact of the requirement to explicitly identify items before judging them old or new.

Discussion of Part 1

Collectively, the findings that emerged from Experiments 1-8 support several main conclusions. First, a robust perceptual-memory effect was observed. Perceptual fluency, indexed in terms of identification speed, was consistently and substantially greater for old items than for new ones. Second, perceptual fluency was consistently and substantially greater for items judged old than for those judged new, regardless of the actual old/new status of the items. Third, this effect obtained only when item identifications and recognition judgments were made successively on each item in turn rather than in separate test blocks. Thus, the effect is attributable to the use of fluency cues in making recognition judgments and not to item-selection artifacts. Fourth, these fluency cues could not be simulated by accelerating item identifications via either clarification rated or semantic priming. Perceptual fluency may have to be produced naturally, such as via perceptual memory, if it is to produce the feeling of familiarity and contribute to recognition judgments. Fifth, the contribution of perceptual fluency to recognition judgments calls into question the utility of recognition memory as an index of explicit memory. Observers can display a reliable level of judgment accuracy even in the absence of explicit memory for items. Finally, although perceptual fluency can influence recognition judgments, its use appears to quickly dissipate as observers gain more explicit memory for old items.

Johnston et al. (1991) concluded their paper with the following speculation: "Given the p ntial ubiquity and primitive status of perceptual memory, it is ii ly to be of some adaptive value to the organism. We suggest that p rceptual memory, through perceptual fluency, yields a rapid if somewhat crude segmentation of the environment into familiar and unfamiliar components. Inasmuch as most organisms grow accustomed to their habitats, unfamiliar components are apt to be relatively rare. Thus, fluent perception accompanied by a general sense of familiarity may be the rule. Any novel intrusion into an otherwise familiar environment may be manifested as a region of low perceptual fluency in an otherwise fluently unfolding perceptual field. In short, perceptual memory may serve as a crude, but quick, novelty detector and thereby make it possible for the organism to be constantly vigilant to environmental change" (Page 22). This line of reasoning formed the basis for our studies of novel popout.

Part 2: Novel Popout

According to standard cognitive theory, the mind comes to represent and anticipate the regularities of its environment. Experience typically yields a dramatic transformation in the nature of perceptual processing. The observer shifts from effortful, unskilled, aschematic, largely bottom-up processing of environmental information to effortless, skilled, schematic, largely top-down processing. This shift from aschematic to schematic perception is highly beneficial; it allows the experienced observer to navigate efficiently through the environment and adapt successfully to it. However, because knowledge-based expectations

infiltrate perception, an occasional cost of expertise and schematic perception is that important changes in the environment go unnoticed, thus militating against appropriate revision of knowledge. Fortunately, schematic perception seems to be opposed by the lesser known phenomenon of novel popout. By ensuring a degree of sensitivity to environmental change, novel popout may guard against the excessive entrenchment of obsolete knowledge. Thus, the perceptual system seems to biased at one and the same time toward both what is expected, via schematic perception, and what is unexpected, via novel popout. The long-term goal of our research program is to discern how the system manages to serve these apparently conflicting functions.

The research summarized here is presented in some detail in Johnston, Hawley, Plewe, Elliott, and DeWitt (1990), Johnston, Hawley, and Farnham (in press), and Johnston, Hawley, and Farnham (under review). Altogether, some 30 studies were performed on novel popout. We summarize below only the most important and illustrative of these studies. They are grouped into three categories: initial studies, boundary conditions, and perceptual bases of NPO. After a summary of these categories of research, we outline our current theory of NPO, called mismatch theory.

Initial Studies

Johnston et al. (1990) summarize several preliminary demonstrations of novel popout and report four main studies in more detail. We describe here the methodological paradigm that emerged from this work and the results of the final main experiment (i.e., Experiment 4), which results we have come to regard as illustrative of the prototypical pattern of effects associated with novel popout.

Method

Observers, usually 36 per experimental group, are given 200-ms glimpses of backward-masked 4-word arrays. Some of the words, called familiar, appear many times across the series of arrays; others, called novel, appear only once. Some arrays, called all-familiar, are composed only of familiar words; others, called all-novel are composed only of novel words; and the rest, called one-novel are composed of one novel word and three familiar words. The locations of both novel and familiar words vary randomly across arrays and, therefore, cannot be predicted in advance. The accuracy with which particular words can be localized is assessed after each array. A probe word is presented, and observers press a key indicating their best guess as to the location that the word had occupied in the array.

Results and Discussion

The results are summarized in Figure 1. Four basic effects are evident. First, accuracy was higher for all-familiar arrays than for all-novel arrays. This baseline effect, a form of perceptual memory, affirms that familiar scenes are more perceptible than novel scenes; it illustrates the efficiency of schematic perception. Nonetheless, the effect of word familiarity was dramatically altered in one-novel arrays. Accuracy of localization in these arrays rose above the all-novel baseline for the lone novel words, defining novel popout (NPO), and fell below the all-familiar baseline for the familiar words, defining familiar sink-in (FSI). These baseline, NPO, and FSI effects define between-arrays effects; they were sufficiently strong that accuracy of localization was actually higher for the novel words in one-novel arrays than for the familiar words in those same arrays, defining within-array NPO/FSI.

As we shall see, the baseline effect and NPO have proven to be more robust and replicable than FSI and within-array NPO/FSI. Potential reasons for these dissociations are addressed in the next section.

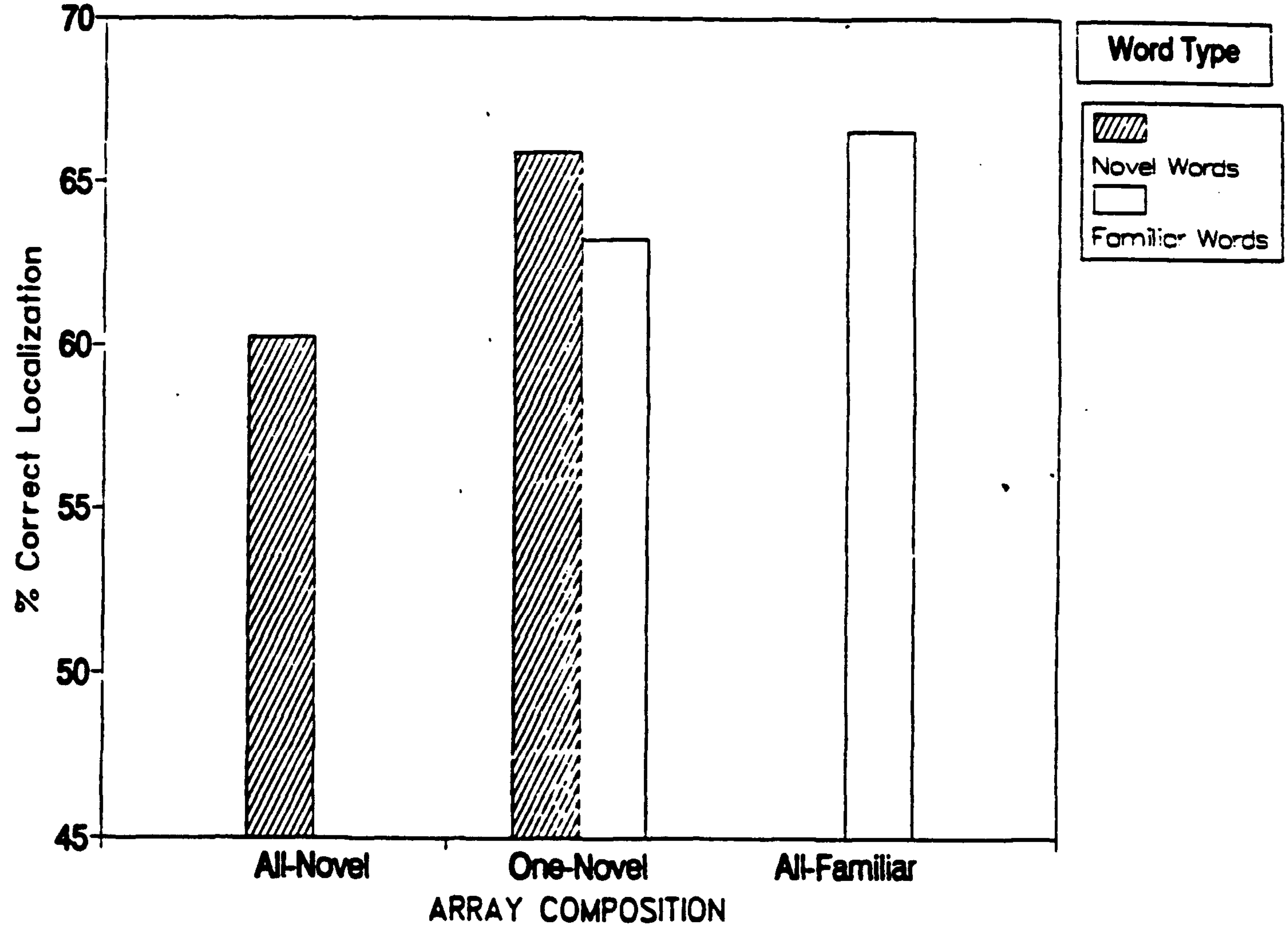

Figure 1. Mean accuracy of localization in Experiment 4 of Johnston et al. (1990) for novel and familiar words in the three array compositions.

Our initial findings discredit certain potential accounts of NPO and place constraints on others. For example, NPO is not attributable to observers perceiving the familiar words in a one-novel array so fluently that they know the location of the novel word by default. This account is undermined by at least two prior findings. First, NPO emerges in word-identification tasks as well as in word-localization tasks (Johnston et al., 1990, preliminary studies). That is, observers of one-novel arrays show enhanced sensitivity not just to the locations of the novel words but to their identities as well. Second, as noted above, within-array NPO/FSI is sometimes observed in which the novel words in one-novel arrays are localized even <u>more</u> accurately than the familiar words with which they appear. Neither is NPO easily attributable to diminished processing of familiar words, such as perceptual satiation and perceptual or memorial confusion. Although such an account could explain the occasional observation of within-array NPO/FSI, it cannot explain the other three effects. For example, if familiarization per se had a deleterious effect on word localization, then the baseline effect would be reversed with localization accuracy being lower, rather than higher, for all-familiar arrays than for all-novel arrays. To account for the full pattern of effects, it appears to be necessary to postulate an actual shift of spatial attention toward the novel words in one-novel arrays and away from the familiar words.

Boundary Conditions

Johnston et al. (in press) explored some of the boundaries within which NPO is confined. Experiments 1-3 of that report examined the effect

of amount of familiarization, or number of repetitions, of the familiar words. Experiment 4 assessed the importance of interitem associations among, or unitization of, the familiar field items. Experiments 5 and 6 tested for the popout of odd familiar words, as opposed to novel items. Finally, Experiment 7 investigated the extent to which NPO survives large reductions in duration of array exposure.

Experiments 1-3

Experiment 1 tested the hypothesis that perceptual memory for individual words composing the familiar fields suffices to produce NPO. In a study phase, observers merely named words that were presented one-at-a-time. In a test phase, our standard word-localization task was performed on arrays composed of all old words, all new words, or one new word in a field of old words. New words did not pop out from fields of old words, indicating that perceptual memory for individual field words does not suffice to produce NPO. Experiment 2 tested the hypothesis that perceptual memory for a whole field of words suffices to produce NPO. Certain critical arrays were arranged in pairs. The second array in a pair contained either all four of the words from the first array or three of the words along with a new, or novel, word. There was no evidence of NPO from repeated fields. Thus, novel words do not pop out from fields composed of words that have been presented just once before, either individually or as a group. Evidently, arrays of words must be presented several times before the fluency with which they are perceived is enough to produce NPO.

In Experiment 3, localization performance for all-familiar and one-novel arrays was assessed as a function of the number of repetitions of the familiar arrays. The findings are summarized in Figure 2.

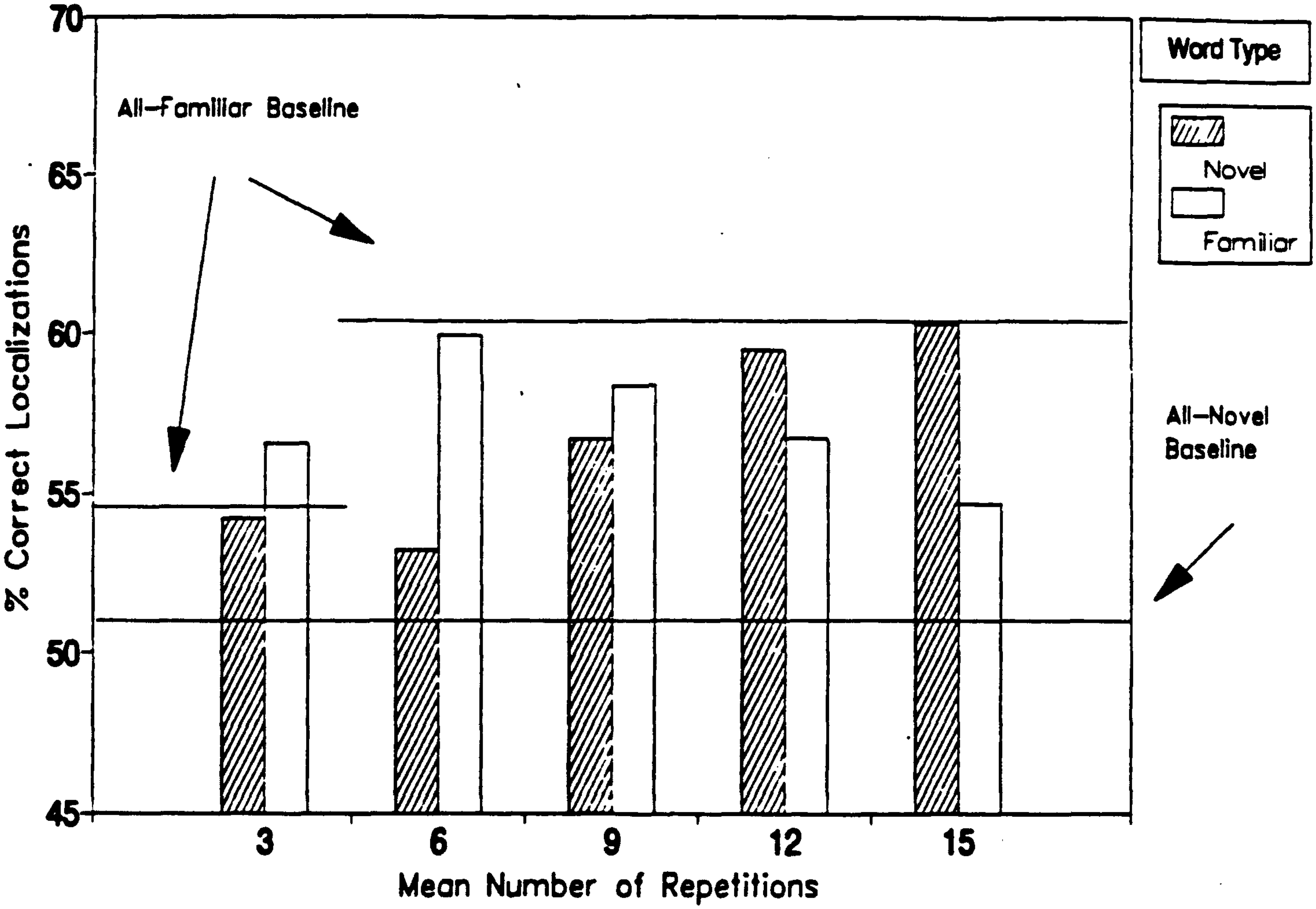

Figure 2. Mean accuracy of localization for novel and familiar words in one-novel arrays as a function of number of repetitions of all-familiar arrays (baselines are indicated by the broken horizontal lines).

The effects of interest emerged between 6 and 15 repetitions of the familiar arrays. After only 6 repetitions, the familiar words in one-novel arrays were localized more accurately than the novel words. However, thereafter, localization accuracy gradually fell for the familiar words in these arrays and rose for the novel words, culminating in strong NPO and FSI effects. The baseline effect attained reliability after only 6 repetitions, NPO after 9 repetitions, and both FSI and between-arrays NPO/FSI after 15 repetitions.

The findings are important in at least three respects. First, they show that the prototypical pattern of effects shown in Figure 1 is replicable. A unique methodological feature of the present study is that each observer experienced 24 different familiar fields in the present study. Thus, NPO does not require that observers be thoroughly familiarized with just one familiar field. Second, the present findings demonstrate that NPO and FSI develop gradually as a function of the frequency with which the familiar arrays have been repeated. Third, the various effects did not bear precisely the same relationship to repetition frequency. Rather, the various effects appear to develop at different rates, with the baseline effect arising relatively early, NPO arising next, and both FSI and within-array NPO/FSI arising relatively late.

Putting aside until later the differential rates of development of NPO and FSI, let us consider the relatively early elevation of the all-familiar baseline above the all-novel baseline. What might it be about the continued repetitions of familiar arrays, beyond the point at which localization accuracy asymptotes, that is responsible for NPO? One

possibility is that NPO depends on the integrity, or unitization, of the familiar fields. Owing to the continued strengthening of interword associations, unitization of the familiar field as a whole may continue to increase long after perceptual memory for individual words has leveled off. Thus, novel words may popout, not so much from a fluently unfolding perceptual field as from a unitized one. The role of field unitization in the production of novel popout was examined in Experiment 4.

Experiment 4

Two types of familiar field were compared: same-set fields composed of words that had appeared many times before and always together, and different-set fields composed of words that had appeared many times before but never together. Same-set fields were assumed to be unitized, and different-set fields nonunitized. If NPO requires that field words be interassociated rather than just individually familiar, then it should be observed only in the case of unitized fields. The results, summarized in Figure 3, confirm this hypothesis. In addition to demonstrating the dependency of NPO on field unitization, Experiment 4 confirms the dissociability, noted with respect to Experiment 3, between NPO and FSI. In this instance, NPO in unitized fields occurred in the complete absence of FSI. Before addressing this dissociation, we consider the possibility that NPO is an instance of a more general odd-popout (OPO) effect.

Another type of array examined in Experiment 4 was a one-odd array. A one-odd array was composed of one word, the odd word, from one familiar set and three words, the unitized field, from a different familiar set. One-odd arrays were included in order to test the possibility that any

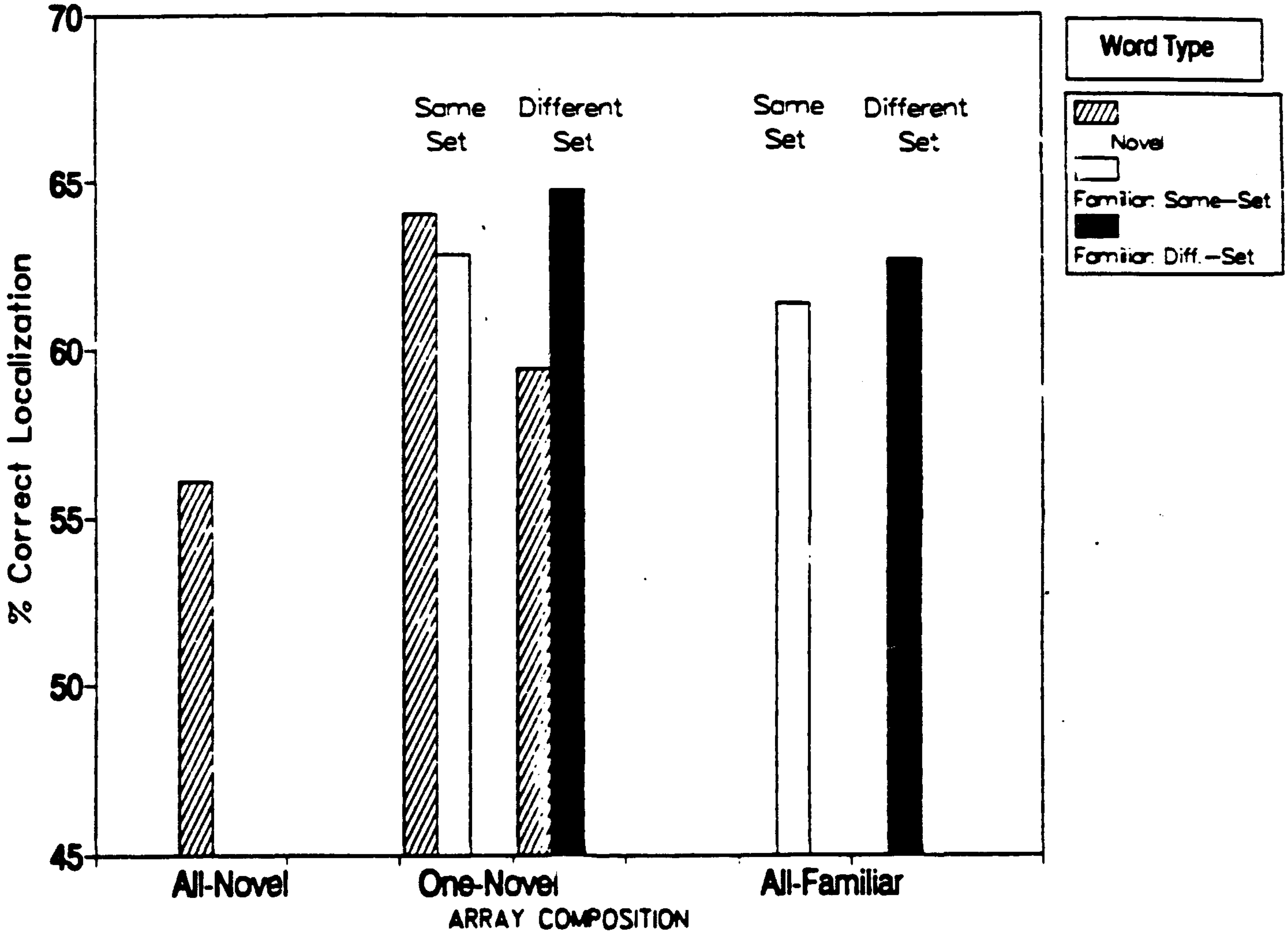

Figure 3. Localization accuracy for novel and familiar words as a function of array composition (all-novel, one-novel, all-familiar) and field unitization (same-set, different-set).

local disparity or oddity in a familiar field draws attention; the odd object may not have to be novel. Even familiar words might pop out if they are transplanted into different, but unitized, familiar fields. Odd popout (OPO) would be demonstrated if localization accuracy for odd words in one-odd arrays rose above the different-set baseline; FSI would be demonstrated if localization accuracy for the field words in one-odd arrays fell below the same-set baseline. As the left panel of Figure 4 shows, neither OPO nor FSI occurred in Experiment 4. However, because the familiar (i.e., same-set) arrays in Experiment 4 were frequently perturbed to form one-odd and different-set arrays, their level of unitization may have dissipated across trials to a level too low to support OPO. Also, because all of the words in the array compositions used to assess OPO were familiar, the 200-ms duration of array exposure may have been long enough to permit the processing of individual words to approach baseline level regardless of any shifts of attention toward or away from them. These possibilities were explored in Experiments 5 and 6.

Experiments 5 and 6

In order to maintain a relatively high level of field unitization in same-set arrays, these arrays remained unperturbed six times more often than they did in Experiment 4. Duration of array exposure remained at 200 ms in Experiment 5 but was reduced to only 83 ms in Experiment 6. The results are summarized in the middle and right panels of Figure 4. Although there was no evidence for OPO or FSI at the longer duration of array exposure, the full complement of the prototypical pattern of NPO effects emerged at the shorter duration of exposure. In addition to

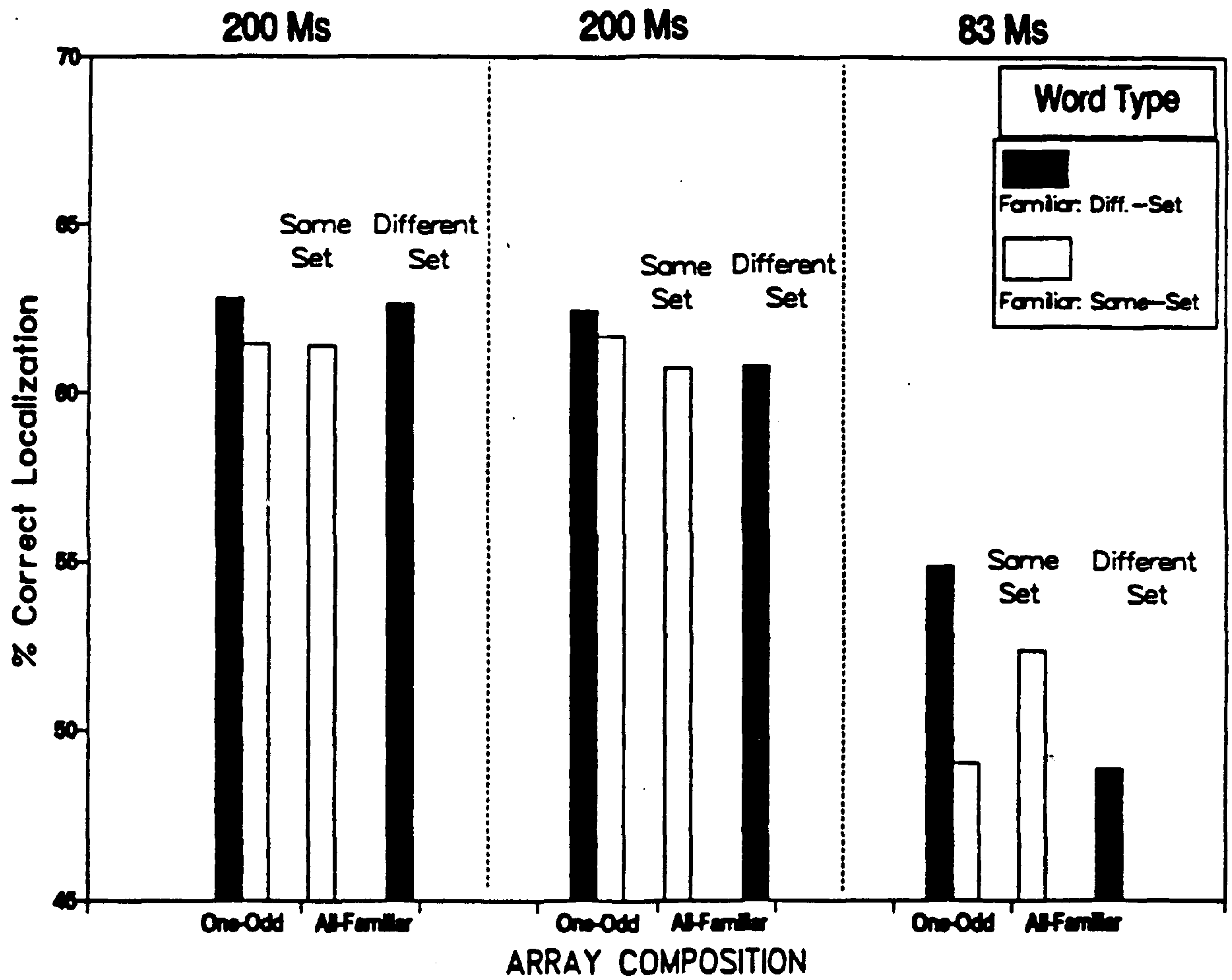

Figure 4. Localization accuracy in one-odd, same-set, and different-set arrays in Experiments 4 (left panel), 5 (middle panel), and 6 (right panel).

demonstrating OPO, the findings of Experiment 6 are striking because one might have expected such a severe reduction in duration of array exposure to eliminate attentional effects rather than enhance them. This observation supports our assumption that perceptual popout is not the result of search strategies or other control processes implemented by the observers. A reduction in duration of array exposure should diminish, rather than augment, any effects of controlled, or directed, attention. Having demonstrated that a reduction in exposure duration draws out OPO and FSI, we next examined its effect on NPO.

Experiment 7

The full unfolding of OPO effects at the shorter duration of array exposure suggested to us that the dissociation observed in Experiments 3 and 4 between NPO and FSI is attributable to the 200-ms duration of array exposure. In particular, the assumed shift of attention to the novel words in one-novel arrays may occur so quickly that enough time is left over in the 200 ms of array exposure for the processing of field words, though attenuated, to approach baseline level. A sufficient reduction in array exposure may prevent the continued processing of field words, thereby exposing the FSI that is concealed at longer exposures.

Each of three groups of observers received both shorter and longer durations of array exposure. The longer duration was the standard 200 ms in all groups, but the shorter duration ranged across groups from 67 ms down to only 33 ms. In order to keep field unitization low enough to produce the dissociation between NPO and FSI at the longer duration, the familiar fields were perturbed at a rate comparable to that used in Experiment 4. The data, summarized in Figure 5, support our line of

reasoning. Whereas the dissociation between NPO and FSI was replicated at the 200 ms duration of array exposure, both effects were evident at all three of the shorter durations. These data provide strong evidence that the dynamics underlying NPO take place very rapidly, clearly within 33 ms.

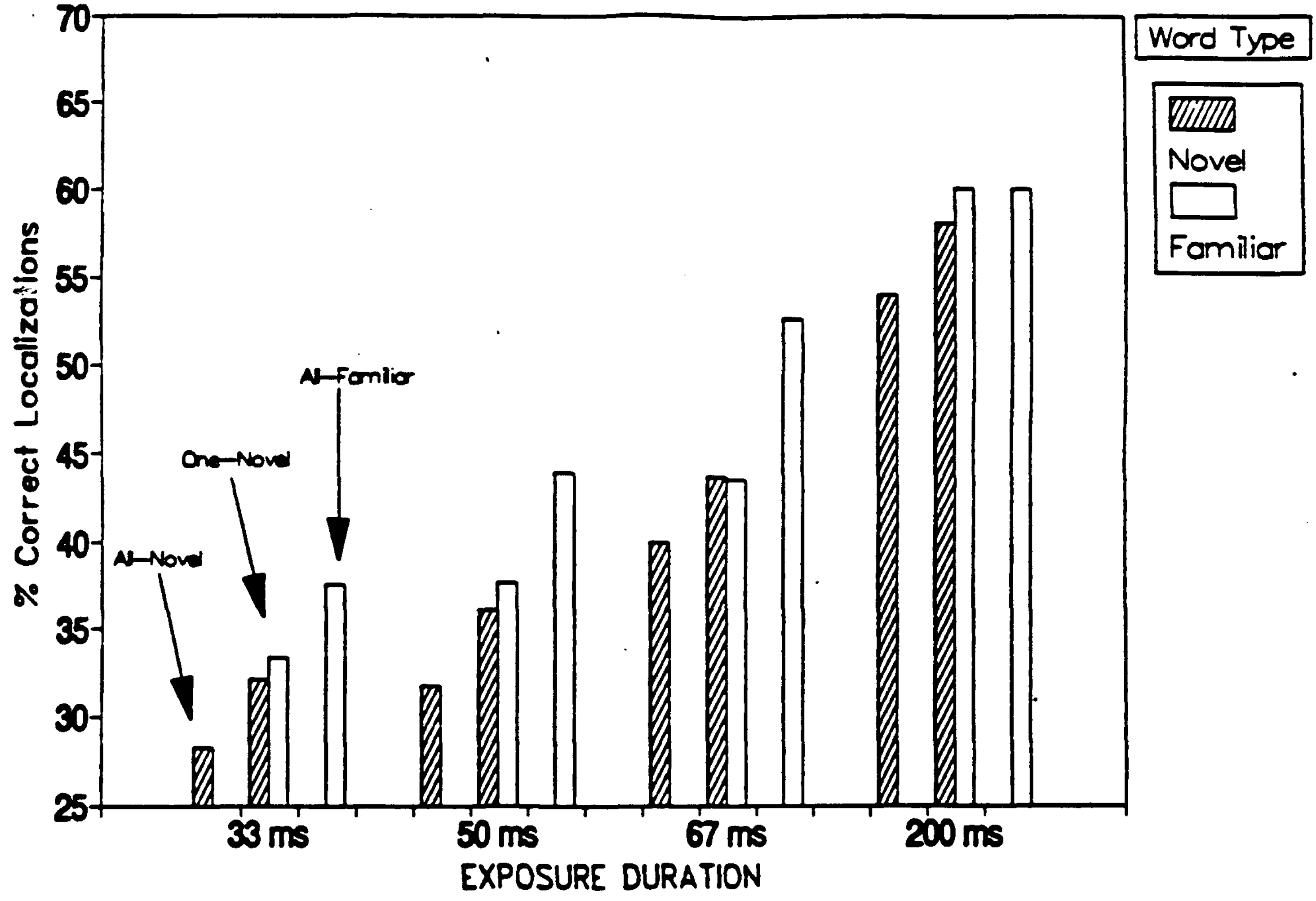

Figure 5. Localization accuracy in Experiment 7 for novel and familiar words as a function of array composition and duration of array exposure.

Perceptual Bases of NPO

The apparent rapidity and automaticity of the shift of attention to novel and odd items raise the possibility that it is based on the analysis of simple features of the items composing the arrays. According to the feature-integration theory of Treisman (1988), the simple features composing a field of objects are analyzed preattentively and in parallel, but the conjunctions of simple features that ordinarily discriminate one complex object from another can be determined only by directing spatial attention to each object in turn. If only simple features can be processed preattentively, then any preattentively-governed capture of attention by novel objects must be based on the novelty of their simple features. Consequently, beyond the level of simple-feature analysis, bottom-up processing might be inhibited for the "expected" field objects and disinhibited for the "unexpected" novel, or otherwise odd, objects.

Although this odd-feature interpretation is appealing, we are disinclined toward it. Inasmuch as the objects used in most of our prior studies were words, with as many as 96 different familiar words composing 24 different fields, it is unlikely that many of the novel words possessed distinctive simple features. Rather, we suspect that the novel words were distinguishable from the field words only in terms of relatively "high-level" perceptual properties. However, because particular novel words may possess simple feature oddities of which we are unaware, the odd-feature interpretation of NPO cannot be dismissed on a-priori grounds. Therefore, one purpose of this category of research was to submit the odd-feature hypothesis to empirical test. In particular, we

examined whether a word printed in one color would pop out from a field of words printed in a different color. Because color oddity should be easily detectable on the basis of simple-feature analysis, odd-color popout (CPO) should be at least as strong and robust as our standard NPO effect.

Another reason for investigating CPO was to provide a benchmark phenomenon by which to evaluate NPO. That NPO should be observed at all, especially at very brief durations of array exposure, may be considered somewhat surprising. In view of the massive evidence that the perceptual system is biased toward familiar and expected stimuli, one might have expected novel words to sink into, rather than pop out from, familiar fields. Still, it would be informative to compare the magnitude of NPO with other forms of perceptual popout. Phenomenologically, figure-ground contrast is clearly higher for odd-colored words in homogeneously-colored fields than for novel words in familiar fields. Thus, CPO may afford a phenomenological yardstick by which to measure and give intuitive perspective to the magnitude of NPO.

Prior investigations of the attention-drawing power of odd colors have produced mixed results. Jonides and Yantis (1988) had observers search for prespecified targets in arrays of up to 7 letters. On occasion, targets happened also to be printed in odd colors. If feature oddity draws attention, then target detection should be facilitated for these odd-colored targets. However, no such evidence of CPO was observed. By contrast, using a task that requires identification, as opposed to just detection, of targets, Martin and Benson (1991) observed that performance was facilitated for targets bearing odd colors. Further observations of a

form of CPO were reported by Folk, Johnston, and Remington (1991). Our procedures provide an alternative means of testing for the automatic capture of attention by odd colors.

Inasmuch as our interest in the possible attention-drawing power of odd features stemmed, in part, from the findings summarized above that NPO remains intact when duration of array exposure is reduced substantially below 200 ms, we deemed it prudent to attempt to replicate this finding before assessing CPO. Thus, Experiment 1 tested for NPO at different durations of array exposure. Experiment 2 then tested for CPO at different durations of array exposure. Whatever simple features might be responsible for NPO, they are not likely to be as conspicuous and reliable as those producing CPO. Thus, CPO might be expected to be larger than NPO and more resistant to the reduction in duration of array exposure. Finally, Experiment 3 tested the possible additivity of NPO and CPO effects. If NPO and CPO are based on the same underlying processes, then they should be additive. If CPO is not as robust as NPO in Experiment 2 and if the two effects are not additive in Experiment 3, then an odd-feature interpretation of NPO will be discredited and the uniqueness and magnitude of NPO might be better appreciated.

Experiment 1

Duration of exposure was manipulated between groups of observers at 67 and 200 ms. As usual, array composition was manipulated within groups at the three levels: all-novel, one-novel, and all-familiar. None of the words appeared in color. The data, summarized in Figure 6, reveal that three components of the prototypical pattern of NPO effects were obtained:

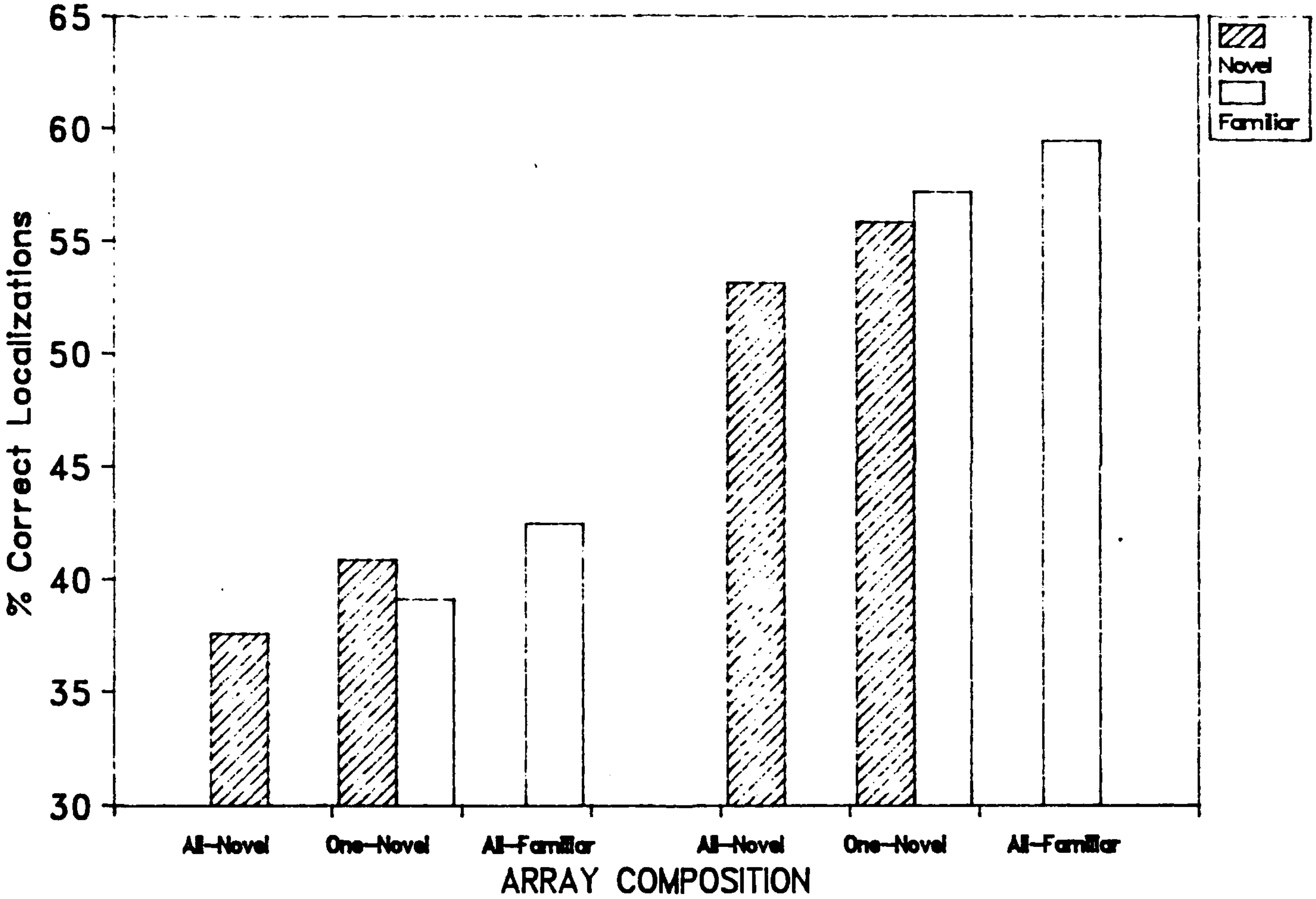

Figure 6. Localization accuracy for novel and familiar words in Experiment 1 as a function of array composition and duration of array exposure.

baseline, NPO, and FSI. Even the elusive within-array NPO/FSI emerged, though only in the second half of the trials. Importantly, none of these effects depended on exposure duration; they were just as evident at 67 ms as they were at 200 ms. The tendency noted above for FSI to emerge only at shorter durations of array exposure was not observed in this study. Evidently, 200 ms did not provide enough time for the processing of the field words to recover from the capture of attention by the lone novel words in one-novel arrays. Thus, the data reaffirm our conclusion that the dynamics underlying NPO take place very quickly, in this case within 67 ms. In an initial test of the odd-feature interpretation of these dynamics, and in the interest of establishing a benchmark by which to appreciate the magnitude of NPO, Experiment 2 investigated whether a comparable pattern of effects would unfold in terms of CPO.

Experiment 2

The design of Experiment 1 was replicated except that the manipulation of word novelty was replaced by a manipulation of word color. All-different arrays were composed of four words printed in different colors, all-same arrays of four words in the same color, and one-different arrays of one word in an odd color and three words in a different color. These arrays corresponded to the all-novel, all-familiar, and one-novel arrays, respectively, of Experiment 1. Duration of array exposure was again manipulated between groups.

The data, summarized in Figure 7, discourage the odd-feature interpretation of NPO. Only weak CPO and FSI effects emerged, and only at the longer duration of array exposure. Neither CPO nor FSI occurred at

the shorter duration; indeed, FSI tended to be replaced by field popout at this duration.

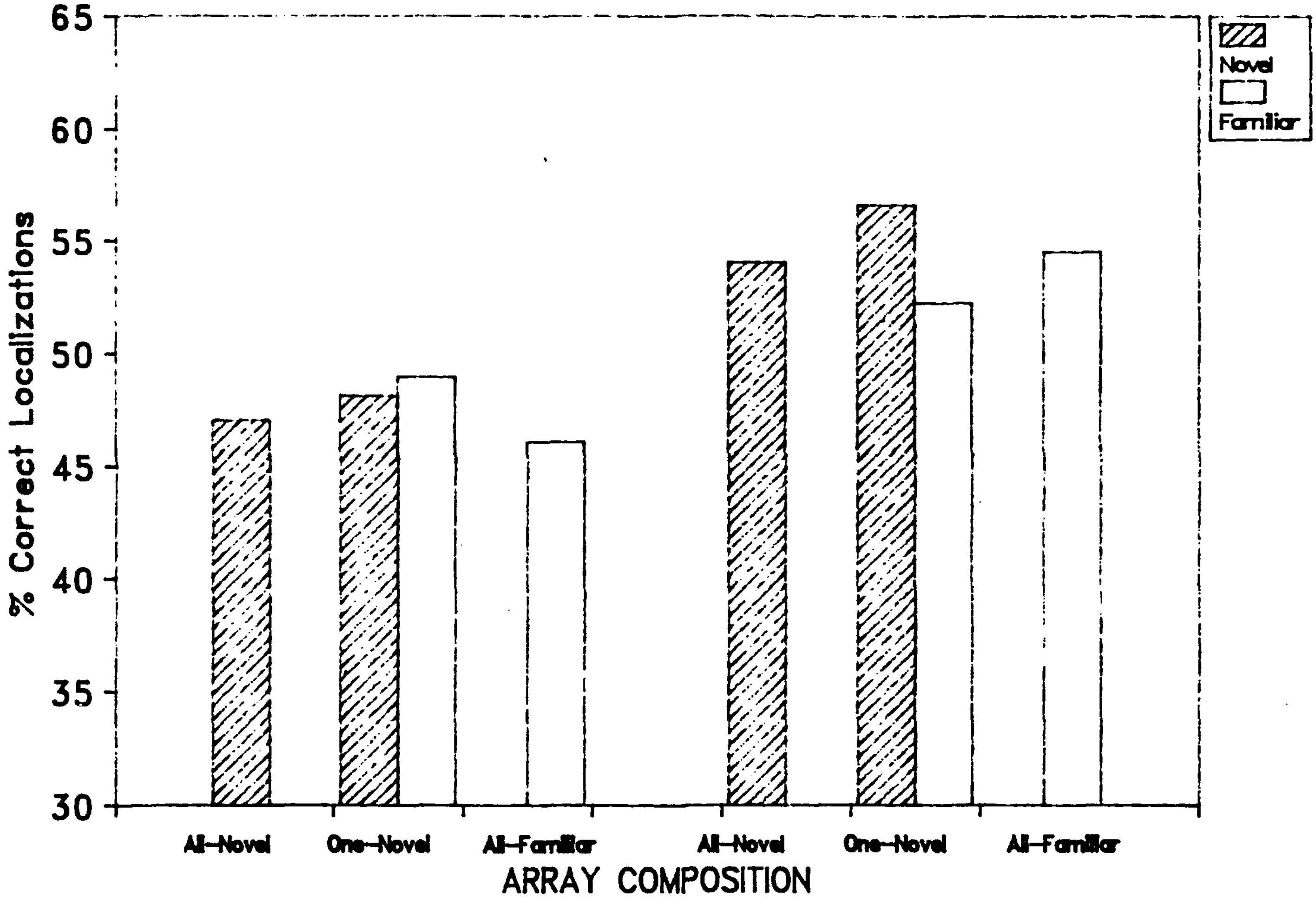

Figure 7. Localization accuracy for odd- and same-colored words in Experiment 2 as a function of array composition and duration of array exposure.

Experiment 3

The failure for strong CPO and FSI effects to occur under conditions comparable to those that produced NPO and FSI in Experiment 1 puts NPO in perspective and discredits an odd-feature interpretation of its bases. However, it is possible that the magnitude of attention capture increases with the number of featural differences between odd and field items and that the stronger effects observed in Experiment 1 were based on multiple featural differences. A single odd feature may not suffice to generate a strong shift of attention. By this view, the addition of color oddity to word novelty should tend to elevate the popout and sink-in effects observed in Experiment 1. Experiment 3 tested this additivity hypothesis by superimposing the color oddity manipulations of Experiment 2 onto the word novelty manipulations of Experiment 1. Thus, Experiment 1 was replicated precisely except that novel words also appeared in odd colors.

The data, shown in Figure 8, offer no support for the additivity hypothesis. The pattern of means closely resembles that for the CPO data shown in Figure 7, with only a weak NPO occuring at the longer duration of array exposure and with familiar popout occuring in lieu of FSI, this time at both durations. If the NPO and FSI effects observed in Experiment 1 were due to the novel words possessing distinctive simple features, then color oddity should have accentuated, rather than suppressed, these effects. In addition to undermining an odd-feature interpretation of NPO, the findings of Experiment 3 indicate that NPO and CPO are based on different dynamics, with those responsible for CPO overriding those responsible for NPO.

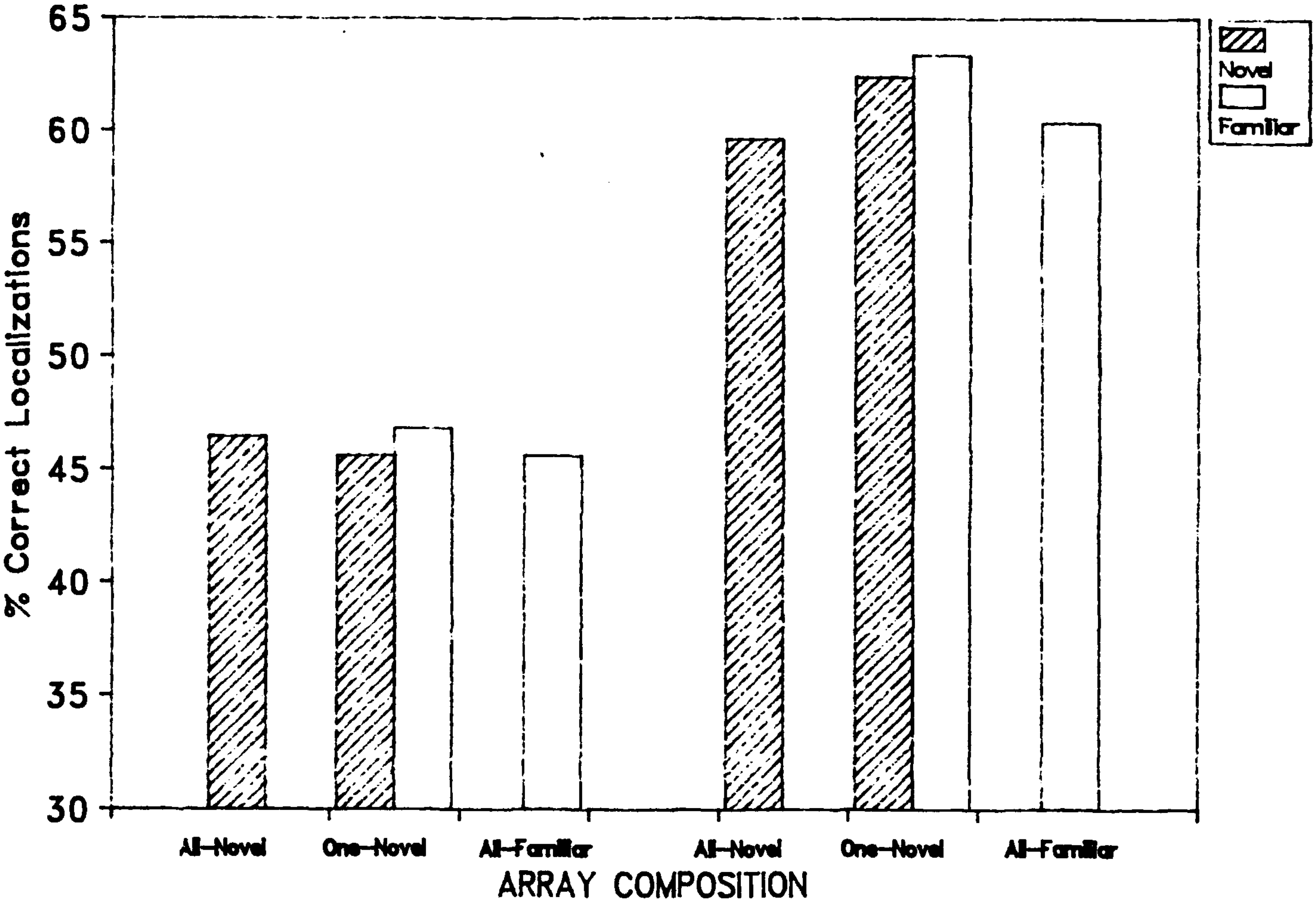

Figure 8. Localization accuracy for odd/novel and field/familiar words in Experiment 3 as a function of array composition and duration of array exposure.

Mismatch Theory of NPO

Collectively, the findings of the three categories of research on NPO lend support to the mismatch theory of NPO proposed by Johnston et al. (in press). The bottom-up activation generated by each object in a familiar field is assumed to spread across associative links to the representations of every other object. Thus, in an organism's familiar habitat, the perceptual representation of a given object receives two sources of activation: that arising from the bottom-up processing of the object itself, and that arising from the spread of activation from the other objects in the field. The result is a match between the bottom-up and top-down sources of activation. This match is assumed to automatically suppress the further bottom-up processing of the object, yielding an overall dampening of the bottom-up processing of familiar environments. Thus, the relatively accurate perception of familiar fields may be dependent more on "knowledge-based" spreading of activation than on direct bottom-up processing.

It is assumed further that the "autoinhibited" bottom-up processing of familiar fields is accompanied by a corresponding reduction in the lateral inhibition across field locations. When a novel object is introduced into such a field, there is a mismatch between the bottom-up processing generated by the novel object and the top-down processing generated by the field objects. Because of the mismatch, there is no autoinhibition of bottom-up processing of the novel object. Moreover, because of the reduced lateral inhibition converging onto the location of the novel object from the perceptually suppressed field objects, there is actually a

disinhibition, or facilitation, of the bottom-up processing of the novel object. This disinhibition causes the novel object to undergo more bottom-up processing than it would in an all-novel array, yielding NPO. In turn, the increased bottom-up processing of the lone novel object generates a corresponding increase in the lateral inhibition that radiates outward from it to the field objects, yielding FSI.

Let us see how mismatch theory accommodates some of our main findings. Experiment 4 of the second category of research showed that objects composing the field must be more than familiar; in order for NPO to emerge, they must be interassociated as well. This finding fits nicely within the framework of mismatch theory; only unitized fields should generate the spreading activation on which mismatch detection is assumed to depend. The OPO and FSI effects observed in Experiment 6 of the second category support the implication of mismatch theory that any disparity or oddity in a unitized familiar field will tend to capture attention; the mismatching object need not be novel. In accordance with mismatch theory, even familiar words were found to pop out when they were transplanted into different, but unitized, familiar fields. Experiment 7 of the second category generated support for a mismatch-theoretic interpretation of the observation that NPO sometimes occurs in the absence of FSI. The mismatch-generated disinhibition of the bottom-up processing of a lone novel word could occur so quickly that enough time remains in the standard 200-ms duration of array exposure for the attenuated processing of the field words to approach baseline level. If this were the case, then a sufficient reduction in duration of array exposure would prohibit this

continued processing of field words and unveil FSI, which result was in fact observed.

Finally, the failure for NPO effects to be duplicated in terms of, or augmented by, CPO effects in the third category of research is consistent with the assumption that mismatch-based disinhibition of novel and odd items is not confined to simple-feature analysis. Any bottom-up data, even high-level conjunctions of features, can partake in the mismatches that define the location of novel and odd items.

In conclusion, we underscore two possible virtues of mismatch theory. First, it solves the problem of how organisms can so fluently process expected stimuli and still remain sensitive to novel stimuli. That is, mismatch theory shows how the same top-down processes that underlie schematic perception lead also to NPO, thereby insuring that the organism makes efficient use of what it already knows about its habitat without forfeiting its sensitivity to novel intrusions. Second, the theory does this without appealing to an attention director or other intelligent agent whose own processing machinery is left unspecified. The so-called "shift of attention" to novel objects is seen as a natural, emergent property of ordinary inhibitory and disinhibitory processes operating on representational units and the connections between them.

General Summary and Conclusions

The experiments summarized in Parts 1 and 2 above support our general thesis that perceptual memory is a ubiquitous phenomenon that plays an important role in ordinary perceptual processing. The experiments summarized in Part 1 provide evidence that perceptual memory for

prior perceptual episodes underlies the feelings of familiarity that are often experienced even in the absence of explicit memory for the prior episodes. This feeling of familiarity may contribute not only to recognition memory judgments; it may contribute also to the emotional contexts and state dependencies upon which much schematic perception and adapative behavior in natural habitats may be based.

The experiments summarized in Part 2 suggest further that perceptual memory may play an important role in keeping the organism vigilant to changes in their natural habitats, allowing for an appropriate revision of the schemata upon which adaptive behavior depends. Perceptual memory for whole fields of objects may be the top-down source of the disinhibition of processing that is assumed by mismatch theory to produce NPO. Thus, perceptual memory may subserve both the efficient processing of environments not perturbed by novel intrusions and the detection of any such intrusions that do occur.

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